

Case Study: CNG Taxis The Republic of Clean Cities

Presented at the 6th National Clean Cities Conference
San Diego, CA
May 10, 2000

Jette Findsen & Julie Doherty
Science Applications International Corporation

Note: The authors would like to gratefully acknowledge Mr. Thomas P. Foltz, Foltz Energy Marketing, Inc., Mr. Jim McCarthy, GRI, Mr. Sean Turner, Engine, Fuel, and Emissions Engineering, Inc., Mr. Michael Wang, Argonne National Laboratory, Mr. Jim Ekmann, NETL, Ms Julianne Klara, NETL, and Mr. Chris Minnucci, SAIC for their contributions to this case study.



Outline

- Case Study Objective
- Background
- Project Description
- GHG reduction measures
- Additionality
- Baseline development
- Monitoring and verification
- Project impacts



Objective

- To illustrate the major issues to be covered in a proposal for the USIJI and other existing/future GHG reduction programs, such as the CDM
 - Information and numbers used in this case study are hypothetical and will be used for illustrative purposes only
 - Although the Clean Cities Republic is considered a “developing country,” it does not represent a specific region or country



The Republic of Clean Cities

- Population: 45 million
- GDP: \$190 billion
 - Annual GDP growth: 5-6% over last 10 years
- Energy resources: oil, natural gas, and hydro
 - Energy demand growth: 7% annually
 - Transportation fastest growing energy sector
- Sectoral share of CO2 emissions:
 - Industrial 52%, **transportation 32%**, residential 13%, commercial 3%
- Non-Annex 1 country under UNFCCC (developing country)
 - Can undertake AIJ projects with any country
 - No binding emission reduction targets under the Kyoto Protocol
 - Eligible for investment under a future CDM



The Capital

- Population of capital area: 8 million
- Population growth (5% / yr)
 - 7 people/motor vehicle (1.3 in the U.S.), total number of vehicles on road growing by 7% annually
- Environmental problems
 - Smog, Ozone, PM growing (among world's 20 most polluted cities)
 - Concentration of total suspended particulates (TSP) in the air 8 x higher than proposed WHO standards
 - Majority of problems caused by transportation



The Capital

- Environmental regulations
 - Tax incentives for switching to alternative fuel vehicles
 - Unleaded gasoline for new cars (40% of gasoline sold is leaded)
 - Car use reduction scheme
 - New domestic regulation put in place for reductions of tail pipe emissions of urban pollutants:

<u>Gasoline Engines (g/bHP-h)</u>			<u>Diesel Engines (g/Kw-h)</u>			
CO	HC	NO _x	CO	HCT	NO _x	PM
37.1	1.9	5.0	4.1	1.1	5.0	0.05



Natural Gas Infrastructure

- New pipeline built to transport natural gas to capital
 - Leakage still minimal
 - Natural gas from oil field where it was previously being flared/vented
 - As a fuel, natural gas is cheaper than gasoline
- No compressed natural gas (CNG) refueling infrastructure in place



The Project

- 75 dedicated CNG taxis (sedans) will be purchased to replace 75 aging gasoline taxis in the capital
- Infrastructure development
 - Construction of 1 new CNG refueling station at the site of the car park
 - Training of taxi fleet mechanics to service vehicles
- Project life time = 10 years
- Each taxi will drive an average of 80,000 miles/yr
- Estimated GHG emission reductions:
 - 10,965.4 tons of CO2 equivalent



Project Participants

- Capital City Transportation Department
- Local taxi fleet operator
- U.S. natural gas vehicle manufacturer



Host Country Approval

- Project has been approved by the Republic of Clean Cities' National Climate Change Office
 - The National Climate Change Office has been authorized by the Ministries of Foreign Affairs, Energy, and Environment to certify JI projects
 - The National Climate Change Office, administered by the Ministry of Energy and Environment, has provided written documentation of project approval



Measures that Reduce GHG Emissions

- Avoided use of oil recovery and gasoline refining/transportation reduces CO₂ emissions
- New CNG vehicles produce lower CO₂ emissions than old gasoline vehicles
- CO₂ emission reductions offset the increased CH₄ emissions from natural gas recovery, pipeline leakage, natural gas compression, etc.
- N₂O emissions remain mostly unchanged and will not be included in the emissions baseline



Additionality (GHG Reduction Measures Initiated as a Result of JI Participation)

- CNG vehicles and refueling infrastructure more expensive than gasoline cars
 - Incremental cost of CNG sedans around \$5,000
- Investment in CNG vehicles not happening without special incentives/funding
 - Lack of capital for investing in vehicles and refueling stations
- USJI participation will help overcome barriers to project implementation
 - JI (and future CDM) participation is likely to increase opportunities for project financing



Are the GHG Reduction Measures Required by Existing Laws or Regulations?

- Current emissions regulations
 - Regulations on vehicle emissions do not include CO₂ and CH₄
 - No laws requiring the conversion from gasoline to CNG
- Answer is no => project is additional



Country Examples of Potential “Additional” AFV Projects

- Chile
- India
- Egypt
- Mexico



Sources of Project Financing

- Specify all sources of financing and the share provided by each participant/investor
 - Financing is covered equally among project participants
- If U.S. federal or multilateral funding sources are provided, explain how these are in excess of those that would have been available for this type of project in the absence of USIJI?
 - None are provided



What to Include in the Emissions Baseline?

Upstream Emissions Sources

- Feedstock (primary energy) production/gathering
 - Includes feedstock recovery, storage, and transportation to fuel processing stage
 - CH₄ from NG venting at oil fields and NG transportation leakage
 - CO₂ from oil recovery and NG flaring at oil fields,
- Fuel processing and transportation
 - Fuel processing and transportation to refueling station
 - CO₂ emissions from gasoline refining; CH₄ leakage during transportation and compression



What to Include in the Emissions Baseline?

Downstream Emissions Sources

- Vehicle Operation
 - Emissions from refueling station to completion of onboard combustion
 - Mostly CO₂ emissions for both NG and gasoline vehicles
 - Represents about 75-80% of emissions for a project switching from conventional gasoline vehicles to natural gas vehicles



Information Constraints for Estimating Upstream Emissions

- Existing full fuel cycle analyses (such as the GREET model) are based on U.S. and Canadian information
 - Data reporting of upstream energy processes required by law
- Similar information is unavailable in many developing countries
 - High transaction costs associated with collecting necessary data



Dealing With Information Constraints

- Under the AIJ Pilot Phase, baseline requirements are loosely defined
 - Dutch/Hungarian CNG bus project looks only at upstream CO₂
- For the purposes of AIJ/USIJI, focus on major gases and emissions sources
 - Explain why some emissions sources are not included and show that project still provides positive GHG benefits
- A future CDM/JI regime under Kyoto Protocol will require more stringent analysis of emission reductions
 - Detailed and credible baselines developed under AIJ are more likely to also be credited under the CDM



Estimating Emission Reductions

- We provide three sample emission baselines ranging from less detailed to very comprehensive:
 - Static baseline focusing on upstream emissions sources
 - Dynamic emissions baseline focusing on upstream emissions sources and changes to equipment etc. over time
 - Dynamic baseline including full fuel cycle analysis and changes to equipment etc. over time
- The choice should depend on:
 - Availability of upstream data
 - individual AIJ/CDM program requirements
 - how accurate project developers want to be
 - how much developers are willing to spend



Assumptions Used For Estimating Emission Reductions

- Numbers used in our study are hypothetical and are loosely based on results from Argonne National Laboratory's GREET model
- GREET indicates that an improvement of more than 30% in GHG benefits can be achieved by replacing a gasoline vehicle with the most efficient CNG passengers cars on the market
 - assumes a CNG vehicle comparable to new Honda Civic GX with fuel economy of 28 miles per gasoline equivalent (city driving)



Assumptions Used For Estimating Emission Reductions

- Compared to U.S. based inputs used in the GREET model, conventional gasoline vehicle emissions are higher in the Republic Of Clean Cities:
 - 40% leaded gasoline in Rep. Of Clean Cities
 - Gasoline refining efficiency 10% lower than in the U.S.
 - Average age of gasoline vehicles to be replaced = 8 years
- Thus, the reference case in our case study shows higher emissions than GREET



Emissions Baseline: Version 1

- Static emissions baseline
 - Looks at upstream emissions only
 - Does not consider changes to vehicle emissions and equipment over time



Version 1: Historic Emissions

Emissions prior to project = “year zero” reference point

- At least 12 consecutive months prior to project
- Includes tail pipe and refueling emissions

	<u>grams/mile</u>	
	Vehicle Operation	Total
CH ₄	0.1	2.1 (0.1 x 21)
CO ₂	410	<u>+ 410</u>
		= 412.1

Emissions 1 year prior to project:

$$412.1 \text{ g CO}_2 \text{ /mile} \times 80,000 \text{ miles} \times 75 \text{ cars} = 2,473 \text{ tons of CO}_2\text{/year}$$



Version 1: the Reference Case

Old gasoline light-weight vehicles (average age = 8 years) would have remained on the road for the next 10 years

	<u>grams/mile</u>	
	Vehicle Operation	Total
CH4	0.1	2.1 (0.1 x 21)
CO2	410	<u>+ 410</u>
		= 412.1

Emissions for 1 project year multiplied by 10:

412.1 g CO2 /mile x 80,000 miles x 75 cars x 10 years = 24,726 tons of CO2 equivalent over life of the project



Version 1: The Project Case

Emissions with natural gas taxis replacing gasoline taxis:

- Includes emissions from CNG refueling station and tail pipes

	<u>grams/mile</u>	
	Vehicle Operation	Total
CH4	0.6	12.6 (0.6 x 21)
CO2	250	<u>+250</u>
		= 262.6

Emissions over 10 years:

262.6 g CO2 /mile x 80,000 miles x 75 cars x 10 years = 15,765 tons of CO2
over life of project



Version 1: Net Project Benefits

Reference case - Project case = Net Benefits

24,726 - 15,765 = 8,961 tons of CO₂ equivalent saved
over life of project



Version 2: Historic Emissions

Emissions prior to project = “year zero” reference point

- At least 12 consecutive months prior to project
- Includes tail pipe and refueling emissions

		<u>grams/mile</u>
	Vehicle Operation	Total
CH4	0.1	2.1 (0.1 x 21)
CO2	410	<u>+410</u>
		= 412.1

Emissions 1 year prior to project:

$$412.1 \text{ g CO}_2 / \text{mile} \times 80,000 \text{ miles} \times 75 \text{ cars} = 2,473 \text{ tons of CO}_2/\text{year}$$



Version 2: the Reference Case

Gasoline vehicles would have remained on the road for the next 10 years

- Emissions will increase exponentially due to equipment failure & aging
- 10% of the vehicles would have been replaced by new gasoline vehicles due to age or accidents, slowing emissions growth

	Vehicle Operation (grams/mile)										<u>Total</u>
<u>Year</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>2004</u>	<u>2005</u>	<u>2006</u>	<u>2007</u>	<u>2008</u>	<u>2009</u>	
CH4	0.1	0.1	0.1	0.11	0.11	0.12	0.12	0.13	0.14	0.15	24.78 (1.18 x 21)
CO2	410	412	414	417	420	423	425	429	434	438	<u>+4,212</u>
											=4,236.78

Emissions for 10 year project:

4,237 g CO₂ /mile x 80,000 miles x 75 cars = 25,421 tons of CO₂ equivalent over life of the project

Version 2: The Project Case

Emissions with natural gas taxis replacing gasoline taxis:

- Includes emissions from CNG refueling station and tail pipes
- Emissions will increase exponentially due to equipment failure & aging
- 4% of the vehicles would have been replaced by new natural gas vehicles due to age or accidents, slowing emissions growth

	Vehicle Operation (grams/mile)										<u>Total</u>
<u>Year</u>	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
CH4	0.6	0.6	0.61	0.61	0.61	0.62	0.62	0.63	0.64	0.65	130 (6.19 x 21)
CO2	250	250	251	251	252	253	254	256	258	261	<u>+2,536</u>
											=2,666

Emissions for 10 year project:

2,666 g CO₂ /mile x 80,000 miles x 75 cars = 15,996 tons of CO₂ equivalent over life of the project



Version 1: Net Project Benefits

Reference case - Project case = Net Benefits

25,421 - 15,996 = 9,425 tons of CO₂ equivalent saved
over life of project



Version 3: Historic Emissions

Emissions prior to project = “year zero” reference point

- At least 12 consecutive months prior to project
- Includes entire fuel cycle

		<u>grams/mile</u>		
	Feedstock	Fuel	Vehicle Operation	Total
CH ₄	0.8	0.08	0.1	21 (0.98 x 21)
CO ₂	30	35	250	<u>+345</u>
				=366

Emissions 1 year prior to project:

$366 \text{ g CO}_2 / \text{mile} \times 80,000 \text{ miles} \times 75 \text{ cars} = 2,196 \text{ tons of CO}_2 \text{ equivalent/year}$



Version 3: the Reference Case

- Gasoline vehicles would have remained on the road for the next 10 years
 - Includes full fuel cycle analysis
 - Emissions will increase exponentially due to equipment failure & aging
 - 10% of the vehicles would have been replaced by new gasoline vehicles due to age or accidents, slowing emissions growth



Version 3: The Reference Case

Feedstock (grams/mile)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH4	0.5	0.5	0.51	0.51	0.52	0.52	0.53	0.54	0.55	0.56
CO2	30	30	31	31	32	33	34	36	38	41

Total

110 (5.24 x 21)
+336
 =346

Fuel (grams/mile)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH4	0.13	0.13	0.131	0.131	0.131	0.132	0.132	0.133	0.134	0.135
CO2	75	75	76	76	77	77	78	79	80	81

28 (1.319 x 21)
+774
 =802

Vehicle Operation (grams/mile)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH4	0.1	0.1	0.1	0.11	0.11	0.12	0.12	0.13	0.14	0.15
CO2	410	412	414	417	420	423	425	429	434	438

25. (1.18 x 21)
+4,212
 =4,237

Emissions for 10 year project:

(346+802+4,237=) 5,385 g CO2 /mile x 80,000 miles x 75 cars = 32,310 tons of CO2 equivalent over life of the project



Version 3: the Project Case

- Emissions with natural gas taxis replacing gasoline taxis:
 - Includes full fuel cycle analysis
 - Emissions will increase exponentially due to equipment failure & aging
 - 4% of the vehicles would have been replaced by new natural gas vehicles due to age or accidents, slowing emissions growth



Version 3: The Project Case

Feedstock (grams/mile)

Total

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH4	0.8	0.8	0.80	0.81	0.81	0.81	0.82	0.82	0.83	0.83
CO2	28	28	29	29	30	30	31	32	33	34

171 (8.10 x 21)

+304

=475

Fuel (grams/mile)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH4	0.08	0.08	0.081	0.081	0.081	0.082	0.082	0.083	0.084	0.085
CO2	35	35	36	36	37	37	38	39	40	41

17 (0.819 x 21)

+374

=391

Vehicle Operation (grams/mile)

Total

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH4	0.6	0.6	0.61	0.61	0.61	0.62	0.62	0.63	0.64	0.65
CO2	250	250	251	251	252	253	254	256	258	261

130 (6.19 x 21)

+2,536

=2,666

Emissions for 10 year project:

(475+391+2,666=) 3,523 g CO2 /mile x 80,000 miles x 75 cars = 21,192 tons of CO2 equivalent over life of the project



Deriving Net Project Benefits

Reference case - Project case = Net Benefits

32,310 - 21,192 = 11,118 tons of CO₂ equivalent saved
over life of project



Assignment of Emissions Reductions

- Emission reduction credits will be shared equally among project developers.
 - 1/3 city government
 - 1/3 taxi fleet operator
 - 1/3 U.S. natural gas vehicle supplier



Factors that Could Cause Anticipated GHG Benefits to be Lost or Reversed

- Natural gas pipeline failure, vehicle/refueling infrastructure failure, adverse market conditions for CNG, investors back out of project
- Steps to reduce risk of reversal:
 - The fleet vehicle operator is fully insured for project failure due to vehicle failure, natural disaster, and/or financial failure



Monitoring

- Parties responsible for monitoring
 - Taxi fleet operators
- Data that will be used for monitoring
 - Energy efficiency and leakage during natural gas compression/refueling
 - Spot vehicle fuel economy and emissions tests will be performed on an annual basis



Verification

- Provisions for external verification
 - Once project has been approved independent verifier will be identified
- Project developers have provided written certification that they agree to external verification



Non-GHG Impacts of Project

- Positive Benefits
 - Improved urban pollution: at least 95% reduction of VOC, 97% reduction of CO, and 64% reduction of NOX compared to conventional gasoline fleet
- Negative Benefits
 - none

